Does a line guide improve reading performance with stand magnifiers?

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Abstract

Background: When reading with a stand magnifier (SM), navigation along each line of text and retracing back to the correct position at the beginning of the next line has been suggested as a major difficulty for people with low vision. In this study, we evaluated the immediate impact of using a simple and inexpensive line guide on navigation performance.

Methods: Twenty-nine participants with age-related macular degeneration read short passages of text using their habitual SM with and without a temporary line guide attached. Magnifier movements were recorded using a 3 SPACE Isotrak system. Reading time, magnifier movement strategies, navigation times and navigation errors were determined. A short questionnaire was used to quantify participants' perceived difficulties with page navigation and their preference for reading with or without the line guide.

Results: For some participants, the line guide improved the control of the vertical positioning of the SM when reading along a line ($p=0.01$), but it increased the number of corrective vertical movements at the end of the retrace ($p=0.001$). There was a small but significant decrease (about 6wpm) in reading speed and increase in navigation times ($p<0.05$) when using the line guide; however 48% participants indicated a preference for reading with it attached to their SM. There was a trend ($p=0.08$) for those who preferred the line guide to report greater habitual difficulties with SM manipulation.

Conclusion: After only minimal instruction in how to use the line guide, forward navigation control improved, but the design of the guide made retracing the SM to the start of the next line more difficult resulting in slower reading speeds. Nevertheless 48% of participants expressed a preference for having the line guide attached to their SM. Improvements to the design of the line guide and strategies that may improve retrace navigation performance are suggested.

Introduction

When reading with low vision, new magnifier users have to learn how to move the unfamiliar device with its restricted field of view to find the start of new lines and read across lines of text (termed "page navigation"[1]). Clinically, it is often found that magnifier users, in particular those with minimal experience, report difficulty with page navigation including accurately repositioning the magnifier at the start of a new line[2], or missing or repeating lines when reading.[3] In an earlier study[2], we used magnifier movement recordings to objectively measure such navigation difficulties. Although only a minority of participants (12%) in that study made a large number of navigation errors, our magnifier movement recordings clearly demonstrated that some participants had difficulty in moving the magnifier along the reading line (forward movement) and/or finding the start of the next line (retrace movement). Any assistance that facilitates page navigation and/or provides orientation to the words being read may improve navigation performance and hence improve reading speed of inexperienced magnifier users.

A few devices have been suggested to assist magnifier reading. These devices include a mechanized reading stand[4], a typoscope placed under the line[3], and a line guide attached to the magnifier.[3, 5] A few commercially-available magnifiers have incorporated reading guides (in the form of a line[a] that can be placed under the text being read or a highlighter with extra illumination[b] in the center of the lens). However, to the authors' knowledge the effect of these reading accessories on navigation and reading performance of people with low vision using optical magnifiers has not been investigated.

In this exploratory study, we investigated the effect of a simple, inexpensive, line guide on navigation performance and reading speed in participants with age-related macular degeneration using their habitual stand magnifiers (SMs). We quantified the movement strategies that were spontaneously adopted when the line guide was first used by

[a] Reading-line magnifiers: E.g. Eschenbach Illuminated Stand Magnifier (1553, 1554, 1559); Schweizer Bar Magnifier (No. 9807 Bar Magnifier, 2.5X; 1.5X) (http://www.lssproducts.com/product/3955/page_and_bar_magnifiers);
[b] Highlighter magnifier: Eschenbach Highlighter (1585-04) and Coil Visual Tracking Line Reader (5850/24, 5850/25, 5850/12, 5850/13)

participants with no previous experience of reading with a line guide attached to their magnifier. We hypothesized that the line guide would modify the movement patterns from those habitually used without a line guide. Specifically, we expected that the line guide would keep the magnifier aligned with the text and that the direction of the movement would be parallel to the lines of text for both the forward and retrace movements. In our previous study of magnifier movements[2] without a line guide, there was a downward element in the movement between the start and end of both the forward and retrace phases; we did not expect to see this downward element when the line guide was used. As our participants were all unfamiliar with using a SM with a line guide attached and received only a short practice session before experimental sessions commenced, we did not expect any improvements in reading performance with the line guide attached. To guide future clinical practice, we evaluated whether there were any vision- or magnifier-related factors that were predictive of a preference to continue to use the line guide.

Methods

Participants

Twenty-nine participants with age-related macular degeneration (AMD) were selected from the Queensland University of Technology (QUT) Vision Rehabilitation Centre (VRC). Data from the magnifier reading without line guide condition for these participants were reported in our earlier study.[2] The four inclusion criteria were: 1) stand magnifiers (SMs) had been prescribed and used as the primary low vision aids for reading; 2) no prior experience of using a line guide attached to a SM; 3) smallest print size that could be read with the SM on Bailey-Lovie word charts was 1.0 M (N8) or better; and 4) critical print size (CPS) with the SM on Bailey-Lovie text reading charts was 1.5 M (N12) or better[c]. CPS is defined as the smallest print size yielding maximum reading speed.

[c] This criterion was to ensure that the print size of passages (1.5 M) used in this study was equal to or larger than the participant's CPS, so that print size of the reading passage (see below) would not limit reading speed.

All participants had received a comprehensive low vision assessment at the VRC within 6 months prior to the study. Each participant had received simple instructions in how to use their SMs as part of their routine clinical care at the VRC, but none had undergone any formal skills training in navigation strategies. Participants used their own SMs for the reading trials in the study. Magnifier usage was quantified in terms of frequency of use (4-point scale), maximum duration of a single use (4-point scale) and time since magnifier was prescribed (months). Difficulties that the participants had with magnifier manipulation in daily reading in their home environment (without a line guide) were determined by asking them to rate on a 5-point scale the difficulty they experienced in: 1) moving the magnifier from word to word along the line (forward navigation) and 2) moving the magnifier back to find the start of the next line (retrace navigation). Participants were all fluent English speakers and gave signed informed consent to their participation. This study followed the tenets of the Declaration of Helsinki and was approved by the QUT Human Research Ethics Committee.

Line guide

Rather than using SMs which incorporate a commercial line guide, we chose to use the participant's own magnifier and apply a temporary line guide. Our aim was to investigate the impact of a line guide on navigation performance for a wide range of visual acuities and magnifier powers. At the time of the study, commercial line guides were only available in relatively low-powered SMs (e.g. 12D and 16D) used by patients with mild acuity losses, and were therefore unsuitable for the purposes of the study.

Based on the clinical experiences of a low-vision trainer, the line guide was made from a white plastic strip with a black fixation patch in the middle of the strip that could be attached easily to any SM. The depth of the line guide and the black patch was always 10 mm (equivalent to 2 lines of text of 1.5 M print) and the length of the guide was always equal to the horizontal diameter of the magnifier. Since it is the central part of a SM that is mostly used when reading,[6] the vertical position of the line guide was standardized with its upper edge placed along the mid-line of the SM (Figure 1). The text above the line

guide was clearly visible while the next two lines of text were blocked. The purpose of the black patch was to direct participants' attention to the reading location as they moved the magnifier along the text. Based on previous clinical experience and some pilot measures, the length of the black patch was customized for each participant so that it was approximately 30% of the measured horizontal field of view (in 1.5M (N12) character spaces) of their SM.

Insert Figure 1

Vision assessment

Vision and reading assessments were conducted monocularly with the eye used for reading or the eye with better near visual acuity if the participant usually read binocularly. Best corrected distance visual acuity was measured using the Bailey-Lovie distance visual acuity chart[7] at 3 m, and near word visual acuity was measured with the Bailey-Lovie word chart[8] at a distance equivalent to the focal length of their habitual near addition, scored to the nearest letter and word respectively. The central 25° visual field was assessed monocularly using a Tangent (Bjerrum) screen at 1 m[9] and contrast sensitivity was assessed by the Pelli-Robson chart at 1 m.[10]

Reading assessment

Participants were required to complete four reading trials, two with and two without the line guide attached to their SMs (see below). The four test passages, along with two practice passages, were derived from standardized children's reading material (Oxford Progressive English Readers, Grades 3 and 4) with reading levels of less than sixth grade (Flesch-Kincaid Grading Level System). This was to ensure that text difficulty did not limit reading speed. Each passage contained approximately 174 standard words (a standard word contains six characters[11]) and was printed in 1.5 M Times Roman font, formatted in one paragraph (12 lines of text) with a line width of 15 cm, left justified and single line spacing. Reading performance was quantified in terms of speed (the number of standard words correctly read per minute - wpm) and reading errors (the number of incorrect words and omissions).

Measurement and analysis of magnifier movements

Movement of the SM was recorded using a 3SPACE Isotrak system (Polhemus Navigation Sciences Division, Kaiser Aerospace, Vermont, USA). Details of the Isotrak and its set up have been described elsewhere.[2] Magnifier movement and navigation performance with and without the line guide attached to the SM were analyzed and quantified using the methods implemented in our previous study.[2] For each reading trial, 10 lines of text were analyzed starting from the initiation of the first clear rightward (forward) movement at the beginning of the second line to the termination of the retrace movement after the 11th line, just before the start of the forward movement on the 12th line. We analyzed the magnifier movements in the forward and retrace phases in terms of: 1) the main direction of the movement - upward, straight or downward; 2) the mean time to complete the movement; 3) the mean horizontal distance the magnifier was moved; and 4) navigation errors, including pauses, regressive magnifier movements, and movements to correct the vertical positioning of the magnifier[2].

Procedures

The text passages were placed on an inclined wooden reading stand for the reading assessments with and without the line guide attached to the SM.[d] All participants were given time to become familiar with the set up by practicing for a short time reading without and then with the line guide attached to their SM until they reported they were familiar with its use. In addition, before recording commenced participants read two complete practice passages (one for habitual magnifier reading and one for magnifier reading with the line guide). Simple instructions were given in how to manipulate the SM when the line guide was attached. These included: 1) placing the SM so that the base was always in contact with the reading stand; 2) placing the line guide underneath the first line of text and always keeping it under the line of text being read; 3) using the black

[d] This arrangement was the best compromise between enabling participants to maintain a comfortable reading posture while providing a standardized experimental setup that would ensure good linearity of the magnifier movement recordings across the whole area of the text passages.

patch as an indicator of where they were reading. However, no instructions were given on how to move the SM across a line of text or from the end of one line to the start of the next when the line guide was attached. This allowed a direct assessment of the movement strategies that were spontaneously adopted when the line guide was first used as an accessory for magnifier reading.

Each participant was instructed to read aloud at their normal reading speed and to read for understanding for each reading condition, "with" and "without" the line guide attached to the SM. Each participant completed two passages for each condition, with the order alternated for each successive participant. Magnifier movements were recorded while they read. At the end of the four reading trials, participants were asked to state whether or not they preferred to use the line guide for their magnifier reading and the reasons for their choice.

Results

The characteristics of the 29 AMD participants and the SMs used are summarized in Table 1.

Magnifier movement characteristics

As reported in our earlier study[2], participants predominantly moved their SMs (without the line guide attached) diagonally downward during both forward (69%) and retrace (55%) phases. However, the introduction of the line guide modified the movement strategy of some participants (Table 2): nine participants changed their forward strategy from a diagonal downward to a straight movement (χ^2=6.05, p=0.01), while six participants changed their retrace strategy, but there was no consistent pattern to the change (χ^2=0.72, p=0.70). Figure 2 illustrates magnifier movements for two participants reading without (left panel) and with the line guide (right panel). In Figure 2a, with the line guide, participant 16 changed his manipulation strategy from diagonal downward to straight in the forward and retrace phases. In contrast, the manipulation strategy in Figure 2b remained the same when participant 1 read with or without the line guide in the

forward phase (diagonally downward), but changed from diagonal downward to upward in the retrace phase.

Insert Figure 2

Comparison of navigation and reading performance with and without a line guide

Table 3 summarizes the results for the magnifier movement parameters, navigation errors and reading measures with and without the line guide. Horizontal magnifier movement distances were significantly longer by an average of 0.8 cm in the forward and retrace phases when the line guide was used ($t=-5.5$, $p<0.001$ for each). These longer movements contributed to significant increases in navigation times (forward time: 1.3s longer, $t=2.13$, $p=0.04$; retrace time: 1.0s longer, $t=2.92$, $p=0.007$). The use of the line guide did not reduce the number of navigation errors, but significantly increased the number of corrective vertical movements made at the end of the retrace compared to the retrace without the line guide (Wilcoxon Signed Rank test, $z=-3.31$, $p=0.001$). Figure 3 shows that participant 25 made more vertical corrective movements at the end of the retrace (the beginning of the next line) when the line guide was attached. These additional vertical corrections contributed to the increase in retrace navigation times and indicated that our participants had more difficulty finding the correct vertical position for the magnifier at the start of each line when the line guide was attached. However, there was an indication that the line guide might help forward navigation because fewer forward vertical corrective movements were made with the line guide attached (but this did not quite reach statistical significance; $z=-1.89$, $p=0.06$).

Insert Figure 3

The overall increase in navigation times when the line guide was attached resulted in reading speeds that were on average 0.04 log wpm (equivalent to 6.1 wpm) slower than without the line guide. Although the impact of the line guide on SM reading performance was small and possibly clinically insignificant, the difference in the reading speed was statistically significant ($t=4.3$, $p<0.001$). There was no significant difference in the number of reading errors with and without the line guide ($t=-0.69$, $p=0.50$).

Preference for the line guide

When questioned at the end of the reading trials, 48% of the participants indicated that they would like to have the line guide to assist their reading with the SM. They reported that the line guide provided better orientation, which allowed them to follow the current line more easily. Participants who preferred the line guide had a shorter history of visual impairment than those who did not prefer the line guide (medians of 12 and 27 months, respectively; Mann-Whitney U=55, p=0.03). However, there was no association between length of time since the magnifier was prescribed and line-guide preference (U=77.5, p=0.23). There were also no significant associations between line-guide preference and any of the other factors we examined (age, distance and near visual acuities, contrast sensitivity, location of scotoma, reading speed, reading errors, magnifier power and field of view, frequency and maximum duration of magnifier use; p>0.09). There was a trend for participants who preferred the line guide to report greater difficulties in manipulating the SM than those who rejected the line guide, particularly with the retrace movement (χ^2=8.1, p=0.08).

Discussion

Does a line guide assist navigation with a SM?

As expected, the introduction of the line guide modified the forward magnifier movements so that they were generally more aligned with the text leading to better vertical position control of the magnifier when reading along the line. However, there was also a significant increase (~10%) in the forward navigation distance which resulted in a significant increase in forward navigation time. The increase in navigation distance might be due to the presence of the black patch in the middle of the line guide. The main purpose of including the black patch was to direct participants' attention to the group of words being read. When using the line guide, participants might have kept their eyes centered in the middle of the magnifier lens above the black patch until they read the last group of words on a line before the SM was moved to the next line. However, without the

line guide participants possibly viewed the last group of words through the edge of the magnifying lens resulting in shorter navigation distances.

Contrary to our expectations, the line guide did not modify the retrace magnifier movements in any consistent manner. Instead the results suggested that retrace was more difficult with the line guide; in particular, participants demonstrated increased difficulty finding the start of the next line (more vertical corrective movements). Retrace navigation times were about 25% longer in duration with the line guide attached (a result of the increase in corrective vertical movements and increase in retrace distance).

The changes in the magnifier movement parameters resulted in a small reduction in reading speed but this is probably of limited clinical significance in view of the short practice period given with the line guide. Our result is similar to the findings of Fitz and colleagues[12] who found that a user-controlled highlighter did not provide any clinically significant short-term improvement in the reading speed of participants with AMD when using electronic magnification. Kuyk *et al.*[4] found that a stationary pointer and a mechanized reading stand resulted in significantly faster magnifier reading speeds, but this is to be expected as the reading stand removed the need for retrace manipulation of the magnifiers.

Preference for the line guide

Although the line guide did not provide any objective improvement in retrace navigation[2], which is typically perceived by AMD magnifier-users as more difficult than forward navigation[2], 48% of our participants expressed a preference for the line guide. There was a trend for participants with greater self-reported retrace difficulties to prefer the inclusion of the guide after the lab-based reading assessments. However, the major reason given for choosing the line guide was the better orientation provided when reading along the line. Duration of vision impairment was the only factor that showed an association with this preference (those who preferred the line guide had vision impairment of more

recent onset), but there may be factors other than those measured in this study that might be predictive of a preference for a line guide.

Design of the line guide

The significant increase in vertical corrective movements at the end of the retrace when using the line guide suggests that the current design is less than optimal. Modifications to the design and more instructions on how to use it could minimize some of the problems that we identified from the magnifier movement recordings.

The location, opacity and width of the line guide substantially reduced the magnifier's vertical field of view and completely blocked the next line of text. This created difficulties in finding the start of the next line, leading to extra corrective movements at the end of the retrace. Using a transparent (or translucent) guide could orientate the readers to the line of text being read but also allow the readers to be aware of the next line as they retraced to the start of that line. Moreover, customizing the width of the line guide to cover 1 line of text and placing it below the midline of the magnifier may be better for reading materials of around 1.5M print. If such a line guide is supplied, specific instructions could be provided, to use a "straight" retrace strategy either back along the line just read or down and back along the next line.

Our results suggest that the short-term practice given in this study was insufficient to allow participants to adequately modify their manipulation techniques for reading with their SMs when the line guide was attached. In addition, by standardizing our experimental set up, the test conditions might have been less than optimal for some of our participants. For those who normally used their SM on a flat tabletop or held the text and SM very close to the eye, or who habitually viewed the text binocularly, our monocular testing may not have accurately reflected their usual performance in reading and/or magnifier navigation. Nevertheless our findings give some useful guidance for clinical practice and future research.

Further research, including sufficient time for each participant to practise with the line guide attached to the SM, a modified design of line guide and instructions on a specific retrace strategy to suit the line guide, is needed. Navigation and reading performance should be assessed before and after two weeks home practice[13] with the line guide attached to the participants' SM. Additionally, a longitudinal controlled clinical trial to investigate the benefit of the line guide, among other strategies, for new magnifier users, including those with other causes of low vision would be beneficial.

Conclusions

After only a limited in-laboratory practice session, participants in this study demonstrated improved forward navigation control with a line guide attached to their SMs (the magnifier movement patterns were more aligned to the text). However, the use of the line guide significantly increased difficulty in finding the start of the next line at the end of the retrace movement, resulting in slower reading speed. Nevertheless 48% of participants stated that they would like to have the line guide on their SMs when reading at home. The line guide used in this study was inexpensive and easily fitted to and removed from any type or power of SM. Simple modifications to the design, specific retrace instructions, and a longer period of home practice may help to overcome some of the identified design limitations.

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Table 1 Descriptive statistics for the 29 AMD SM users

	Mean	**Standard deviation**	**Min**	**Max**
Age (years)	80	6	65	89
Distance visual acuity (logMAR)	0.81	0.33	0.12	1.36
Near word acuity (logMAR)	0.97	0.37	0.10	1.50
Contrast sensitivity (log)	0.99	0.27	0.45	1.45
Visual field loss	83% participants had a scotoma within the central 5° radius of the visual field			
SM experience	5 months*	0.63 – 5.3**	3 days	5 years
SM frequency of use	70% participants used their SM either frequently or regularly (at least once per day for at least 5 minutes at any one time)			
SM equivalent viewing distance (cm)	8.51	5.77	2.2 (45D)	22.3 (4.5D)
SM horizontal field of view (number of characters)	14.5	8.2	6	40

* Median

** Interquartile range

Table 2 Percent of participants using each of the main magnifier movement categories with and without the line guide attached to their SM

		Straight	**Diagonal downward**	**Upward**	**P value**
Forward movement	Without line guide	38%	69%	-	**0.01**
	With line guide	62%	31%	-	
Retrace movement	Without line guide	24%	55%	21%	0.70
	With line guide	28%	62%	10%	

Table 3 Descriptive statistics (mean ± SD) for magnifier movement parameters, navigation errors and reading performance using a SM with and without a line guide

		Without line guide	With line guide	P value
Magnifier movement parameters	Forward distance (cm)	12.1 ± 1.7	12.9 ± 1.4	**<0.001**
	Forward time (sec)	15.6 ± 11.2	16.9 ± 11.7	**0.04**
	Retrace distance (cm)	12.1 ± 1.7	12.9 ± 1.1	**<0.001**
	Retrace time (sec)	4.06 ± 2.22	5.07 ± 3.01	**0.007**
	Total magnifier movement time (sec)	19.6 ± 12.8	21.9 ± 14.4	**0.003**
Navigation errors (in terms of number per passage) +	Forward regression	2.50 IQR: 0.5 to 6.75	2.0 IQR: 0.0 to 6.75	0.37
	Forward vertical corrective movement	0.50 IQR: 0.0 to 2.5	0.50 IQR: 0.0 to 1.25	**0.06**
	Retrace regression	1.0 IQR: 0.0 to 2.75	1.0 IQR: 0.5 to 2.0	0.84
	Retrace vertical corrective movement	2.0 IQR: 0.5 to 3.75	3.5 IQR: 1.0 to 5.5	**0.001**
Reading performance	Log reading speed (log wpm)	1.77 ± 0.26	1.73 ± 0.27	**<0.001**
	Reading errors (words)	5.64 ± 6.64	6.41 ± 6.54	0.50

+ Because of the non-normal distribution of navigation errors, median and interquartile ranges (IQR) were reported.

Figure Caption

Figure 1

Line guide attached to the underside of a stand magnifier. The line guide was made from a white plastic strip with a black fixation patch in the middle. The depth of the line guide and the black patch was 10 mm (equivalent to 2 lines of 1.5M text) but the length of both varied, dependent on the SM and the participant's field of view. This type of line guide is inexpensive and could easily be fitted to any stand magnifier.

Figure 2

Original magnifier movement traces (thin blue lines) showing horizontal (X) and vertical (Y) positions of a magnifier without a line guide (left panels) and with a line guide (right panels) attached. To aid interpretation, simplified traces highlighting forward (thick green line long dashes) and retrace (thick orange line short dashes) movements have been superimposed and data are shown for 3 lines only with the vertical axes on a larger scale than the horizontal axes. Magnifier movement patterns for the forward and retrace phases are categorized as straight (no difference in vertical position), upward (if the end position was more than 3mm higher than the start position) or downward (if the end position was more than 3mm lower than the start position).[2]

Figure 2a. Participant 16 used a stand magnifier with equivalent viewing distance[14] of 12.9 cm (equivalent power of 7.8D). Without the line guide, the magnifier was moved diagonally downward during both the forward and retrace phases. With the line guide, both the forward and retrace changed to 'straight' movements (much less change in vertical position between the start and end of each movement). This participant made very few navigation errors.

Figure 2b. Participant 1 used a stand magnifier with equivalent viewing distance of 15.2cm (equivalent power of 6.6D). Without the line guide, the magnifier was moved diagonally downward during both the forward and retrace phases. With the line guide, the forward movement remained the same but the retrace movement changed to predominantly upward.

Figure 3

Participant 25 used a stand magnifier with equivalent viewing distance of 2.65 cm (equivalent power 37.7D). Without the line guide, this participant made a number of navigation errors, including missing a line, regressive magnifier movements in the forward phase with and without the line guide, and vertical positioning errors at the end of the retrace (represented by the dashed rectangular bars with grey color overlaid and labeled "Vertical retrace"). With the line guide attached, the vertical positioning errors in the retrace significantly increased.

Figure 1

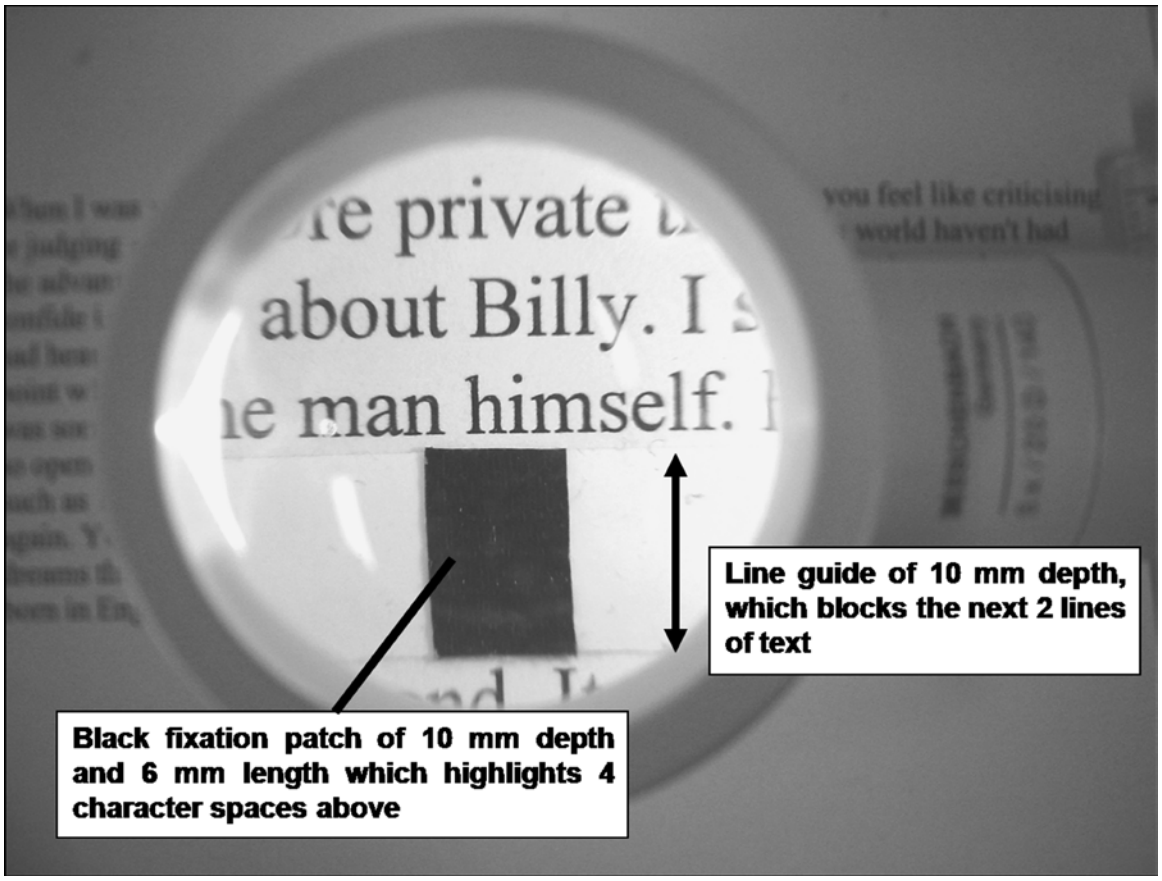


Figure 2a

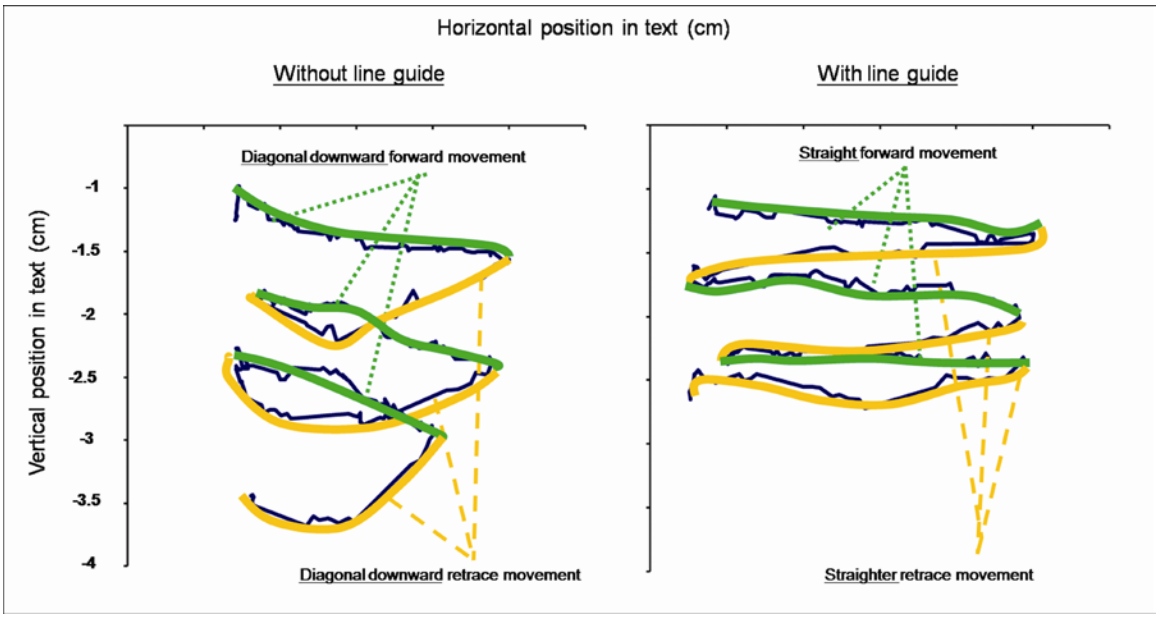


Figure 2b

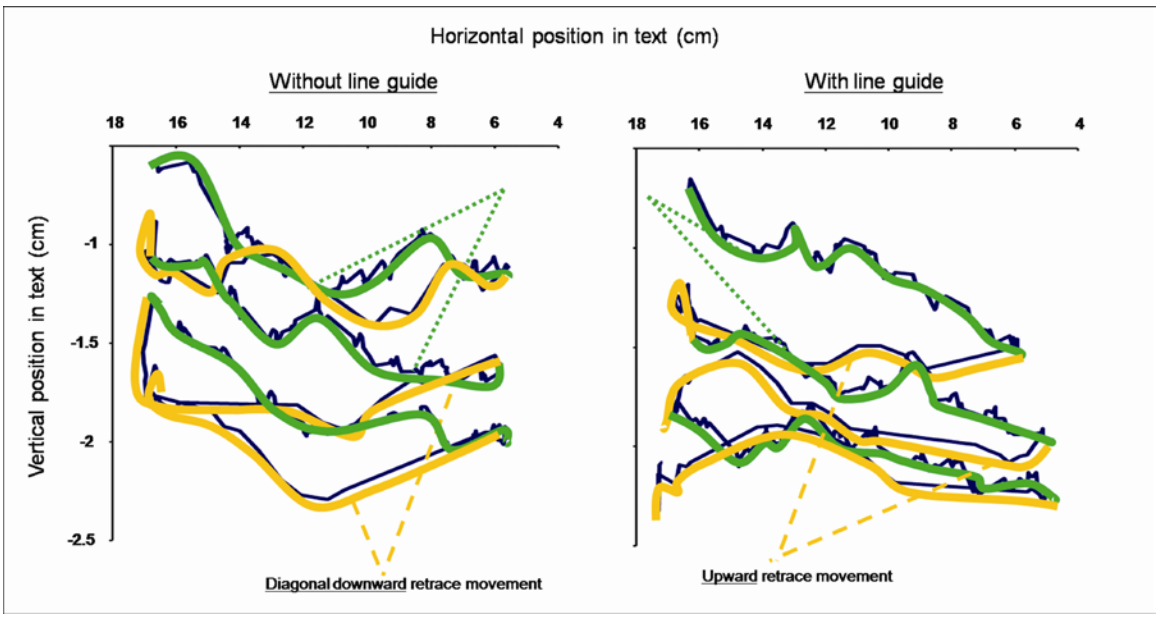
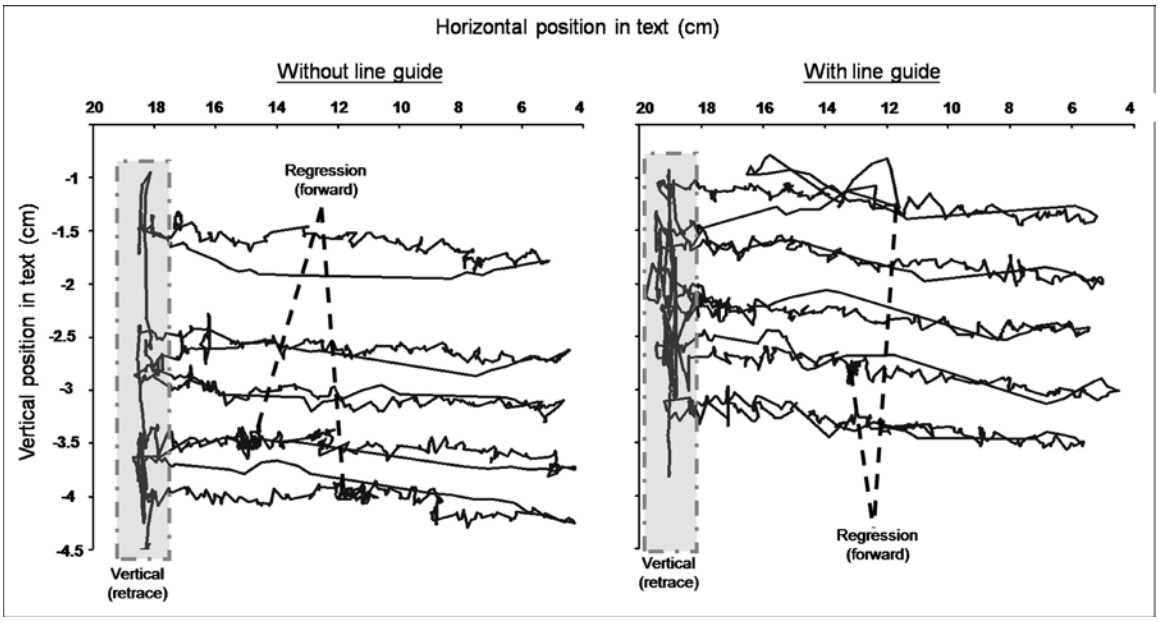


Figure 3


Horizontal position in text (cm)
Without line guide
With line guide
20
18
16
14
12
10
8
6
4
Vertical position in text (cm)
-1
-1.5
-2
-2.5
-3
-3.5
-4
-4.5
Regression
(forward)
Vertical
(retrace)
Regression
(forward)
Vertical
(retrace)